

The QuadCAT Four-Way Catalytic Converter

An Integrated Emission Control
System for Diesel Engines

presented to the:



California
Air Resources Board

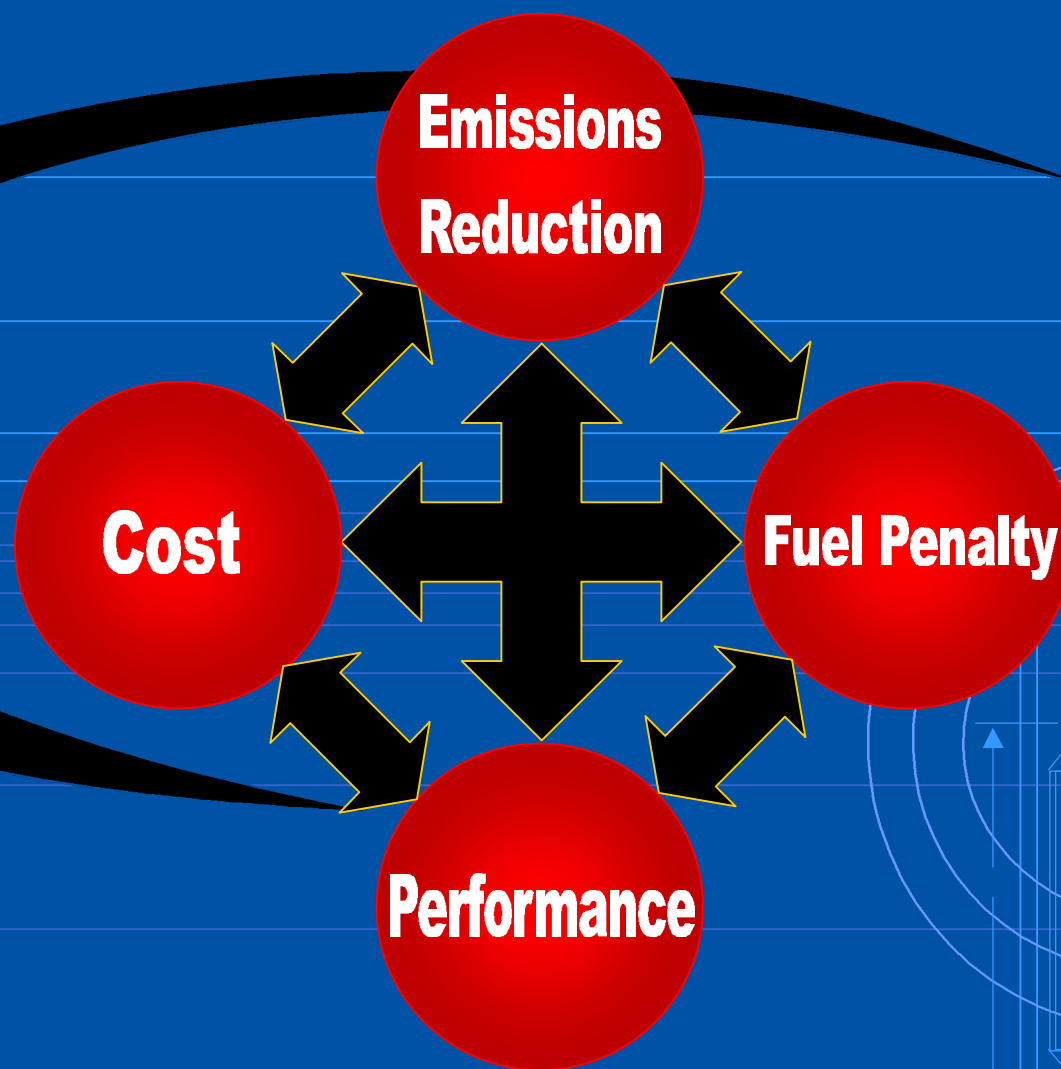
February 3, 2000

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Ceryx Vision

**Systems that
balance Cost,
Performance,
Emissions
Reduction,
and Fuel
Penalty
to make the
economics of
pollution
control viable**



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Emission Standards

U.S. and Europe



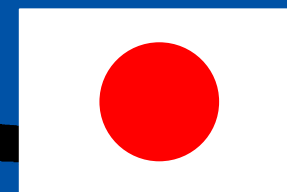
	<i>HC</i>	<i>CO</i>	<i>PM</i>	<i>NOx</i>
	<i>grams per brake horsepower hour</i>			
1998 Baseline	1.3	15.5	0.1	4.0
2004 U.S. Federal (2002)	0.5 (62%)*	15.5 (0%)	0.1 (0%)	2.0 (50%)
Euro IV (2005)	0.4 (69%)	1.1 (93%)	0.015 (85%)	2.6 (35%)
ULEV (Clean Fleet Program)	N/A	7.1 (46%)	0.05 (50%)	2.8 (30%)

**Percent reduction in relation to baseline*

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Emission Standards: Japan



CO HC NOx PM
grams per kilometer (mean)

Passenger Cars

<1265 kg (1997)	2.10	0.40	0.40	0.08
<1265 kg (2002)	0.63	0.12	0.28	0.052

Commercial Vehicles

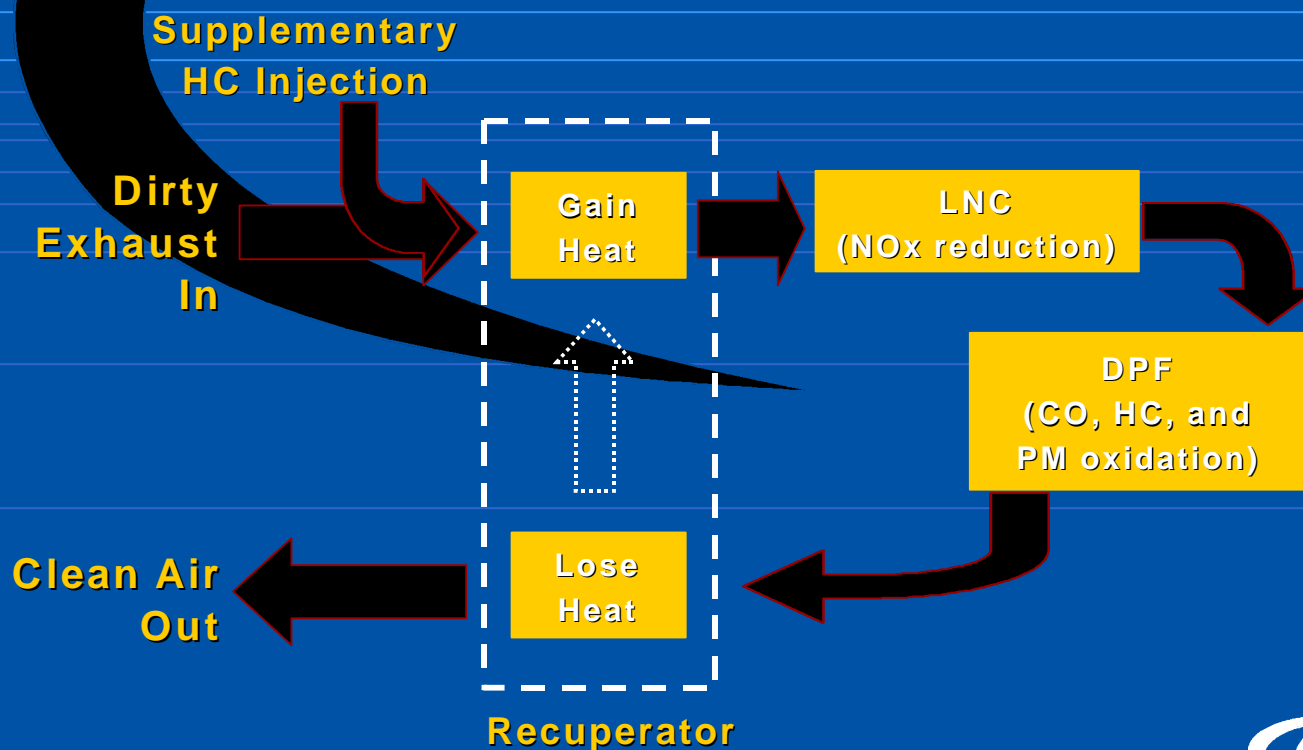
2,500-12,000 kg (1997/98)	7.40	2.90	4.50	0.25
>12,000 kg (2004)	2.22	0.87	3.38	0.18

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QuadCAT Flow Schematic

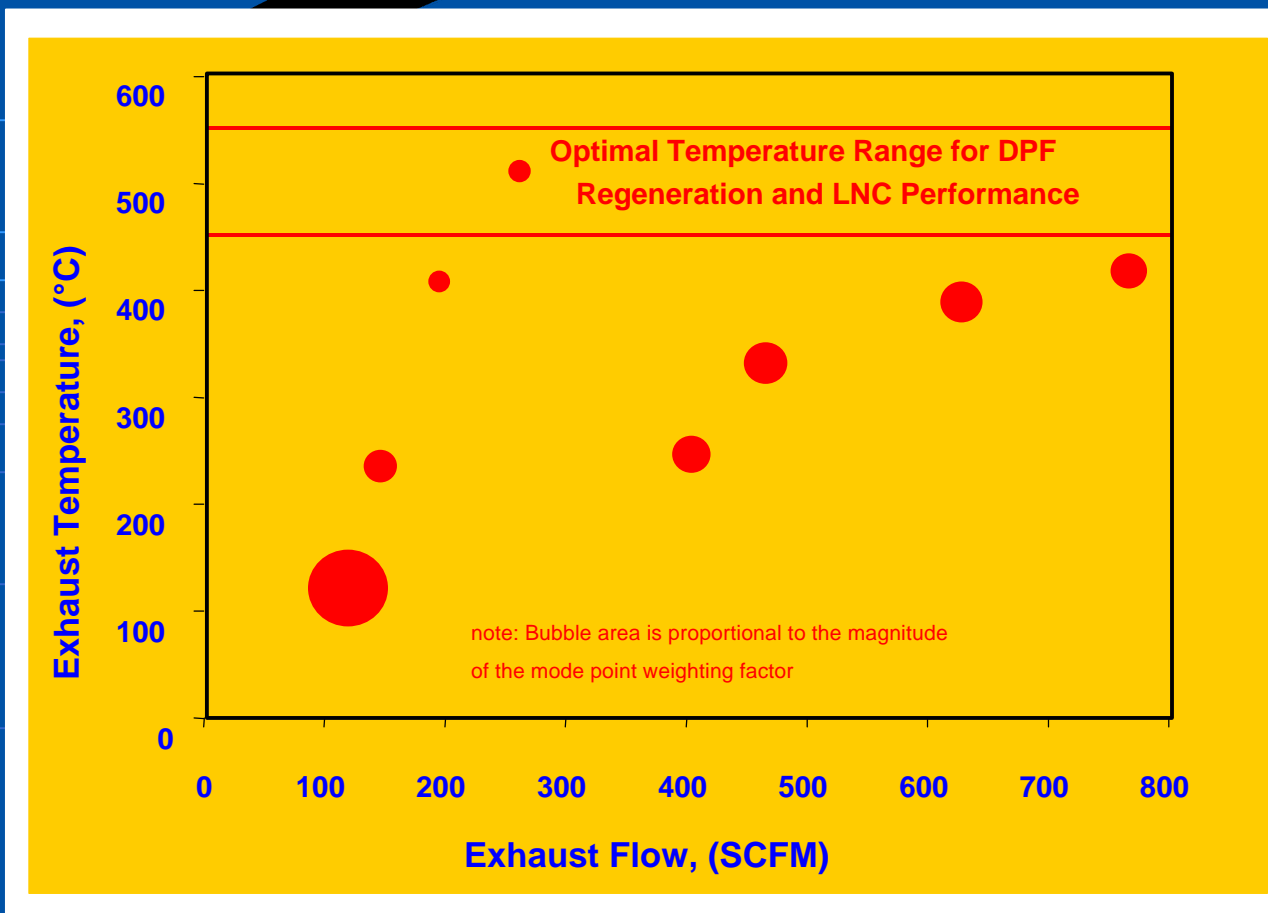
- © Integrate heat transfer and chemistry for simultaneous reduction of NO_x, CO, HC, & PM



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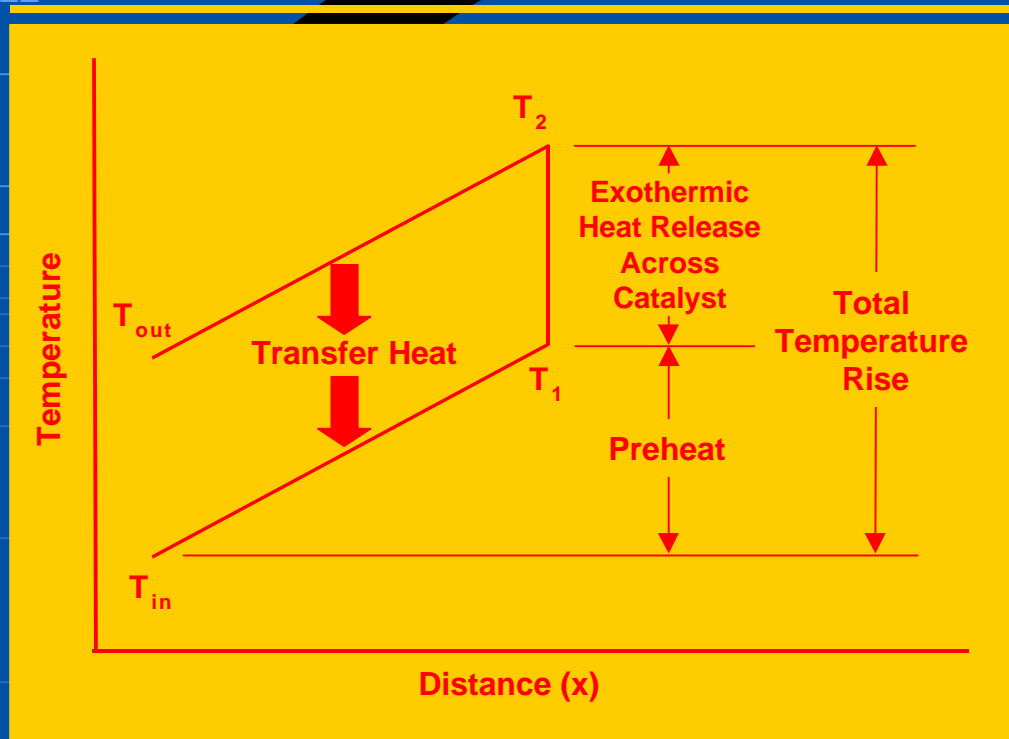
Temperature Profile Over 8-Mode Heavy-Duty Cycle



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Chemical Reactor Platform



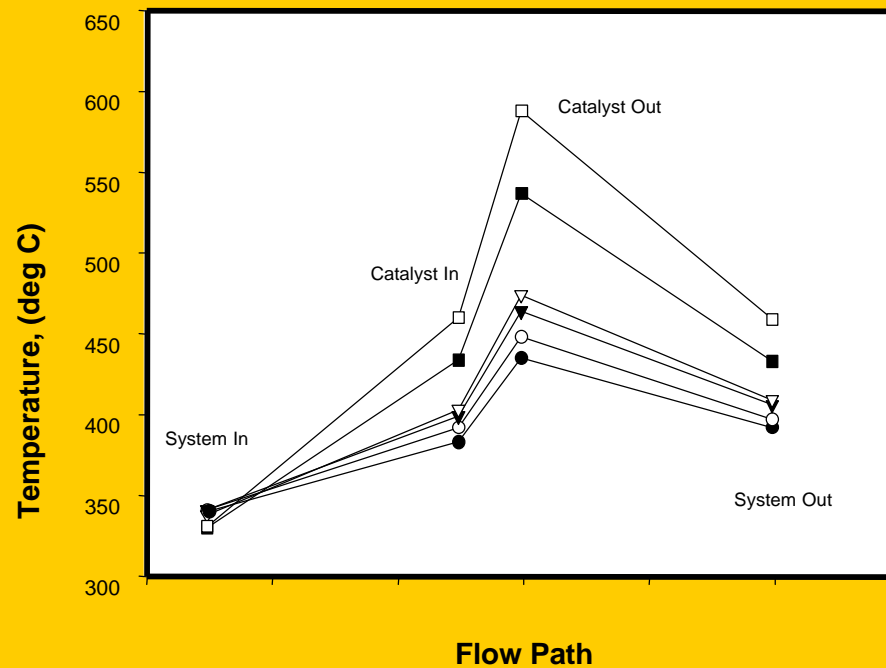
© Recycle heat from exothermic reactions

© Increase catalyst temperature

© Effectiveness defined as:

$$\eta = (T_1 - T_{in}) / (T_2 - T_{in})$$

Experimental Data with Light-Duty Prototype on 200 Hp Engine



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Integration Makes Full Use of Resources

Injecting supplementary HC provides:

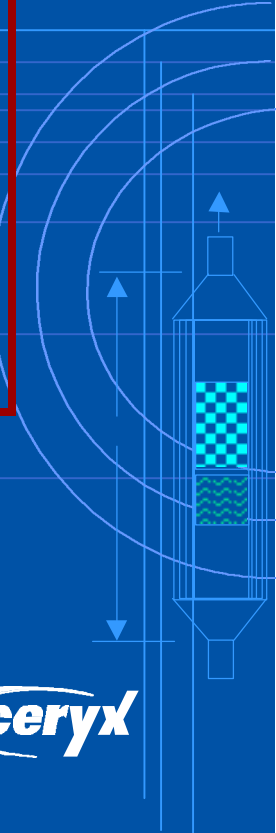
Energy source for DPF regeneration



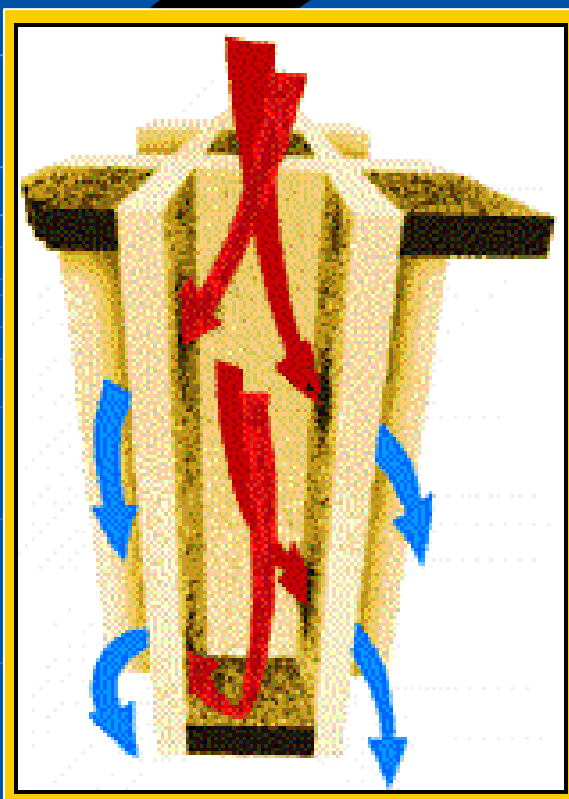
Reducing agent for NOx catalyst



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Diesel Particulate Filters

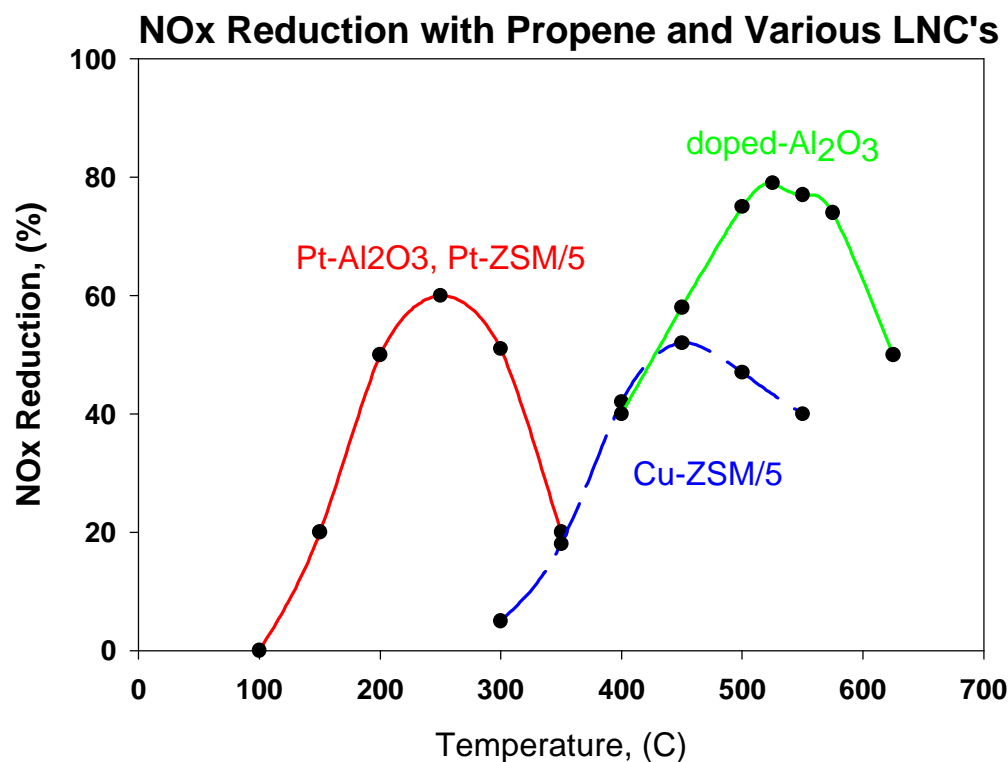


- ◎ **Very high filtration efficiency (>90%)**
- ◎ **Variety of configurations**
- ◎ **Regeneration requires elevated temperatures to oxidize PM:**
 - ◎ 550°C-650°C Uncatalyzed
 - ◎ 380°C-450°C Catalyzed
 - ◎ 200°C-400°C with fuel borne additives such as cerium or platinum

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Lean NOx Catalysts

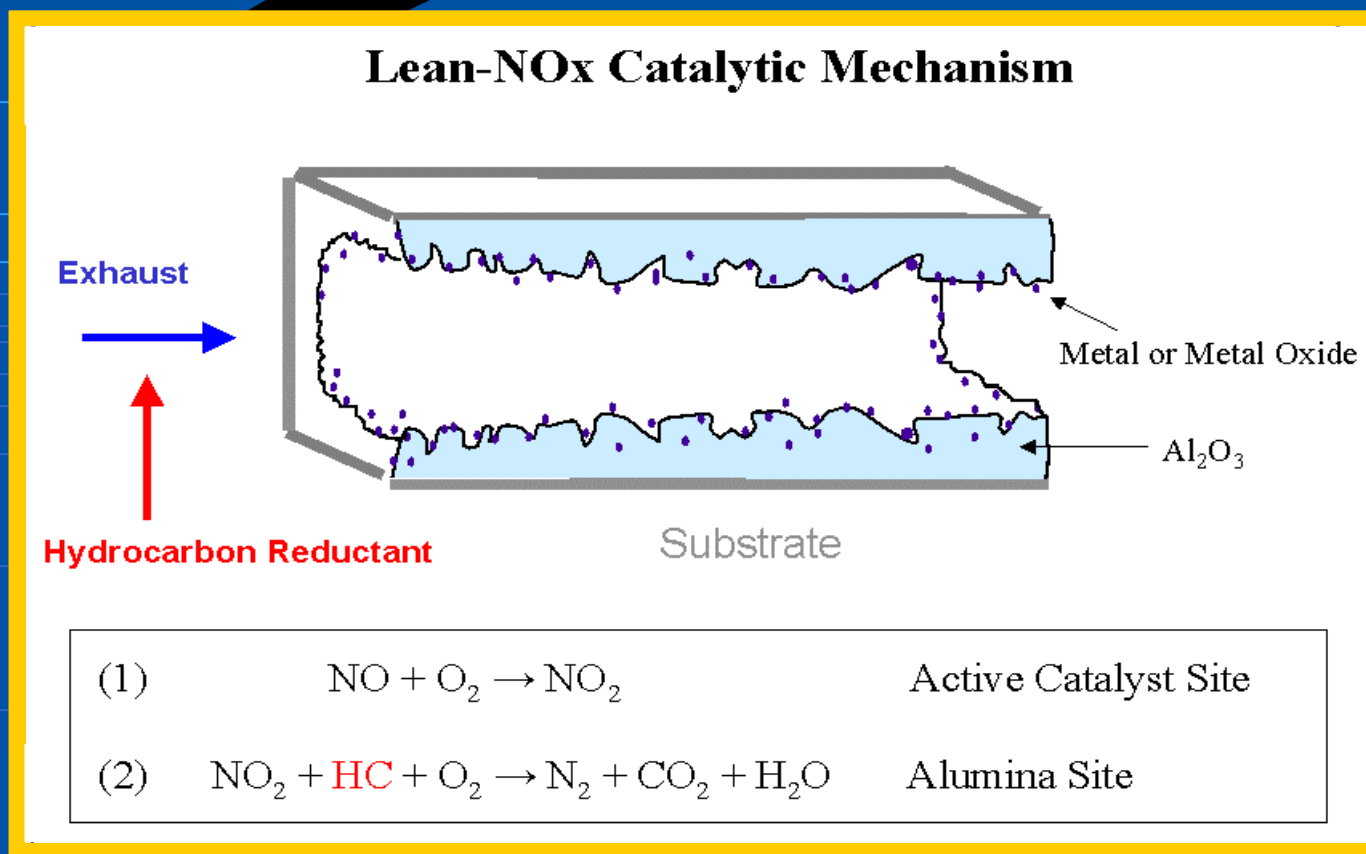


- © Many formulations with various temperature windows
- © Best reductions at elevated temperatures
- © Low-cost, non-precious metal based catalyst are durable and sulfur tolerant
- © Could benefit from QuadCAT recuperative approach

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Lean NOx Catalyst Mechanism



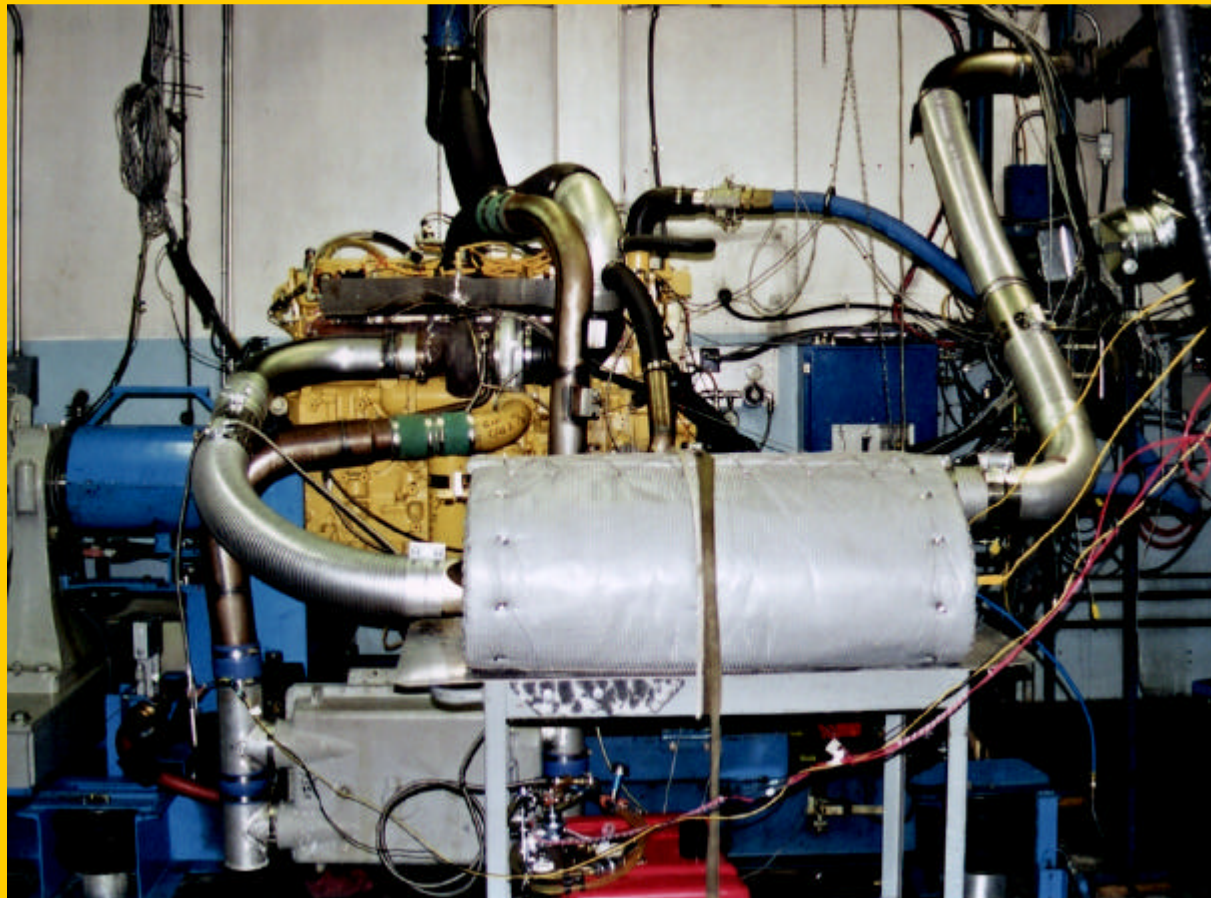
Ceryx Offers Multiple Configurations in a Single Platform

<u>Product</u>	<u>HC</u>	<u>CO</u>	<u>PM</u>	<u>NOx</u>
© LeanCAT™ (Lean NOx Catalyst +DOC)	>90%	>90%	>30%	30-50%
© QuadCAT™ (Lean NOx Catalyst + DPF)	>90%	>90%	>90%	30-50%
© QuinCAT™ (NOx Trap + DPF)	>90%	>90%	>90%	>90%

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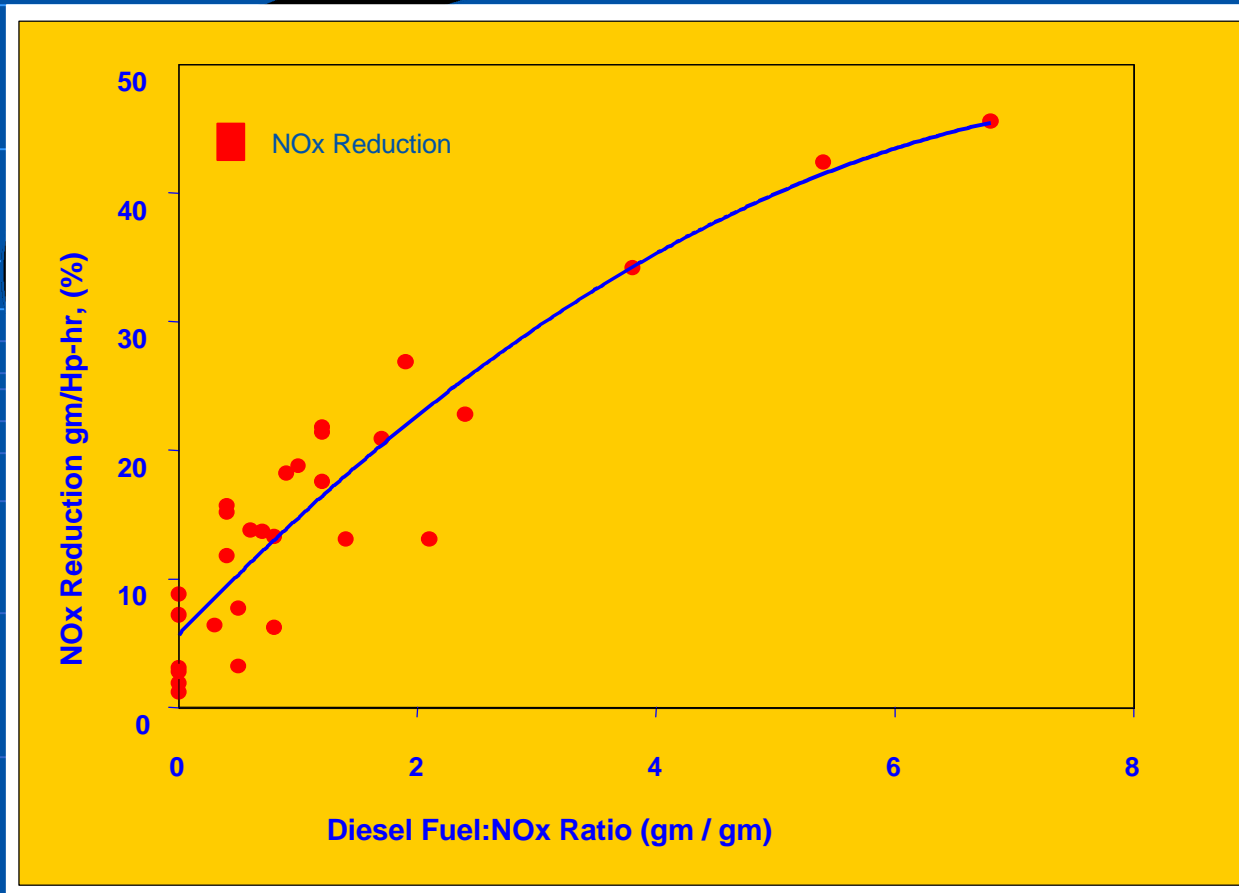
QuadCAT Prototype Testing



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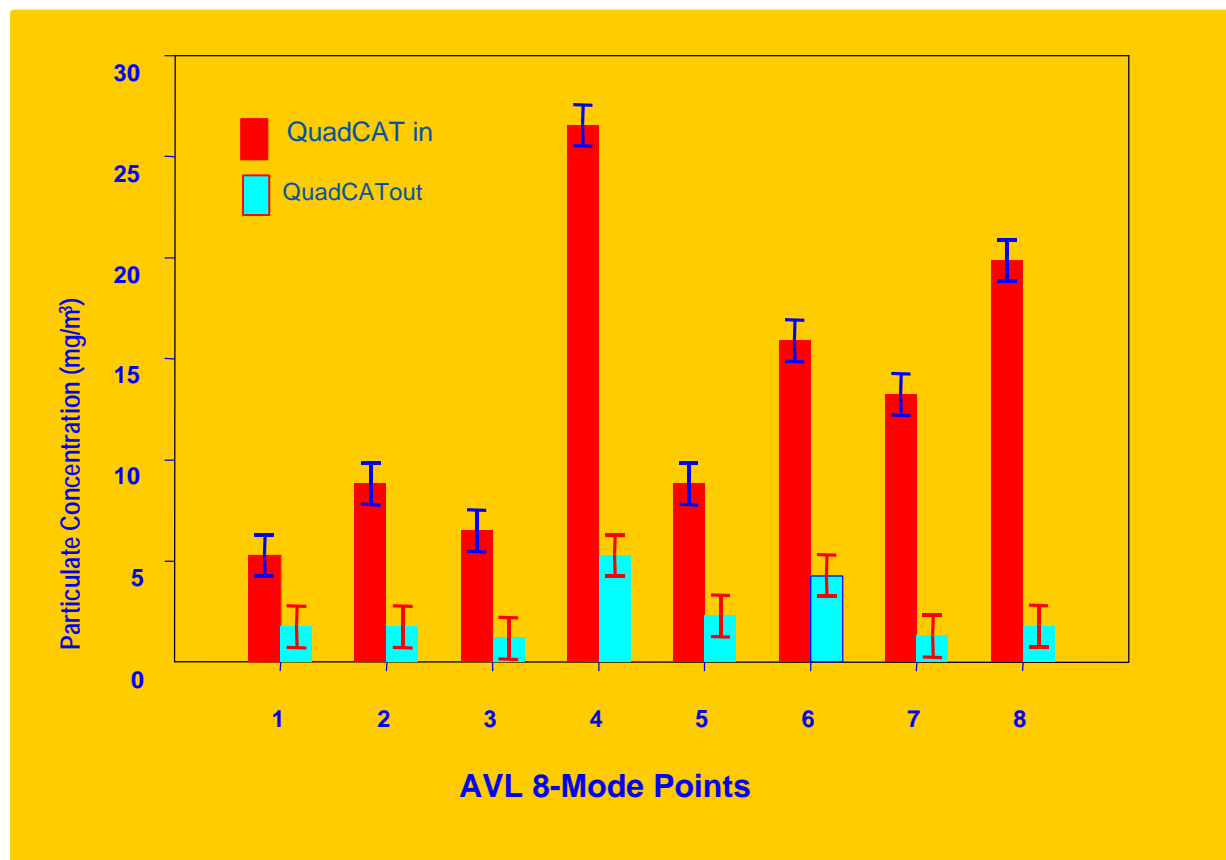
Results: NOx Reduction



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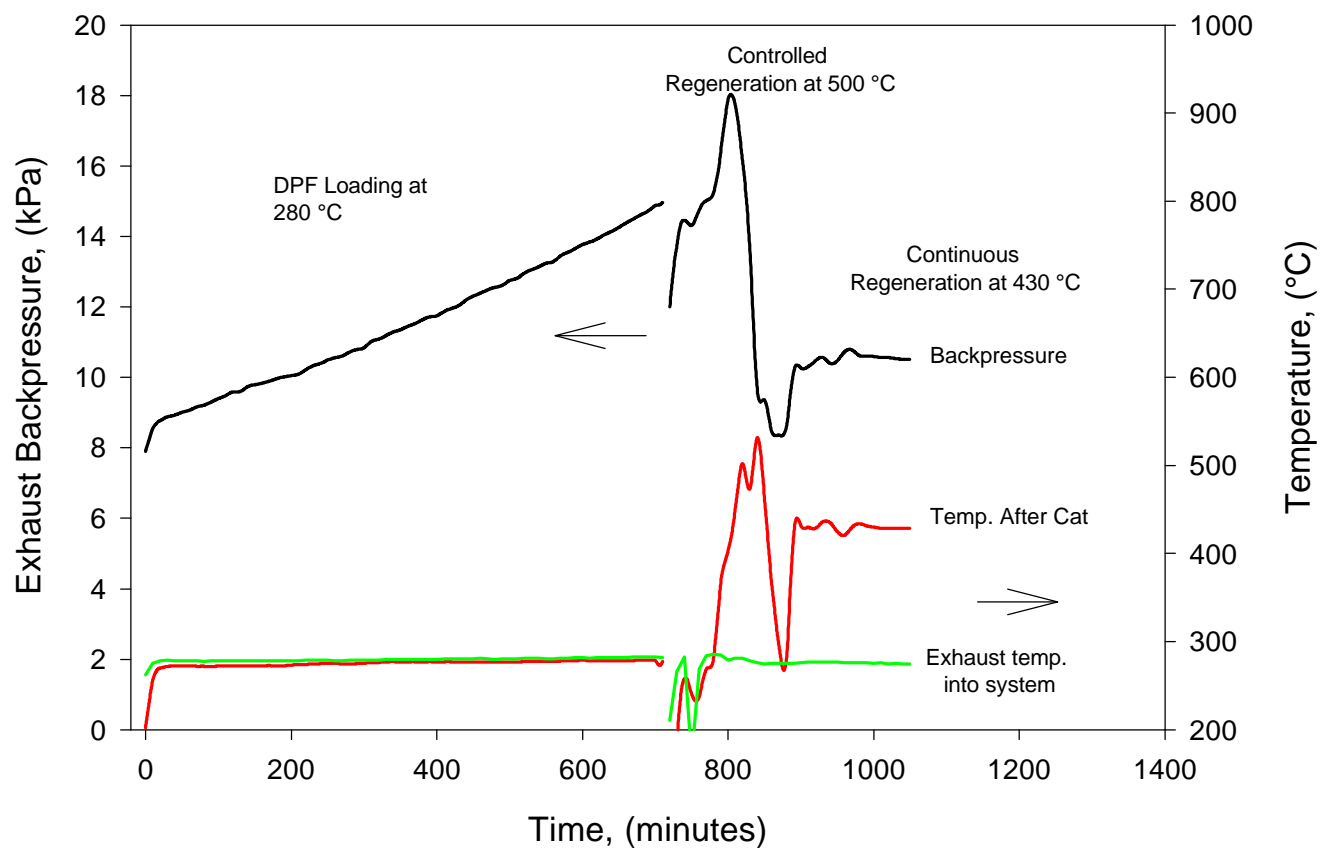
Results: PM Reduction



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DPF Regeneration Data



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The QuadCAT System

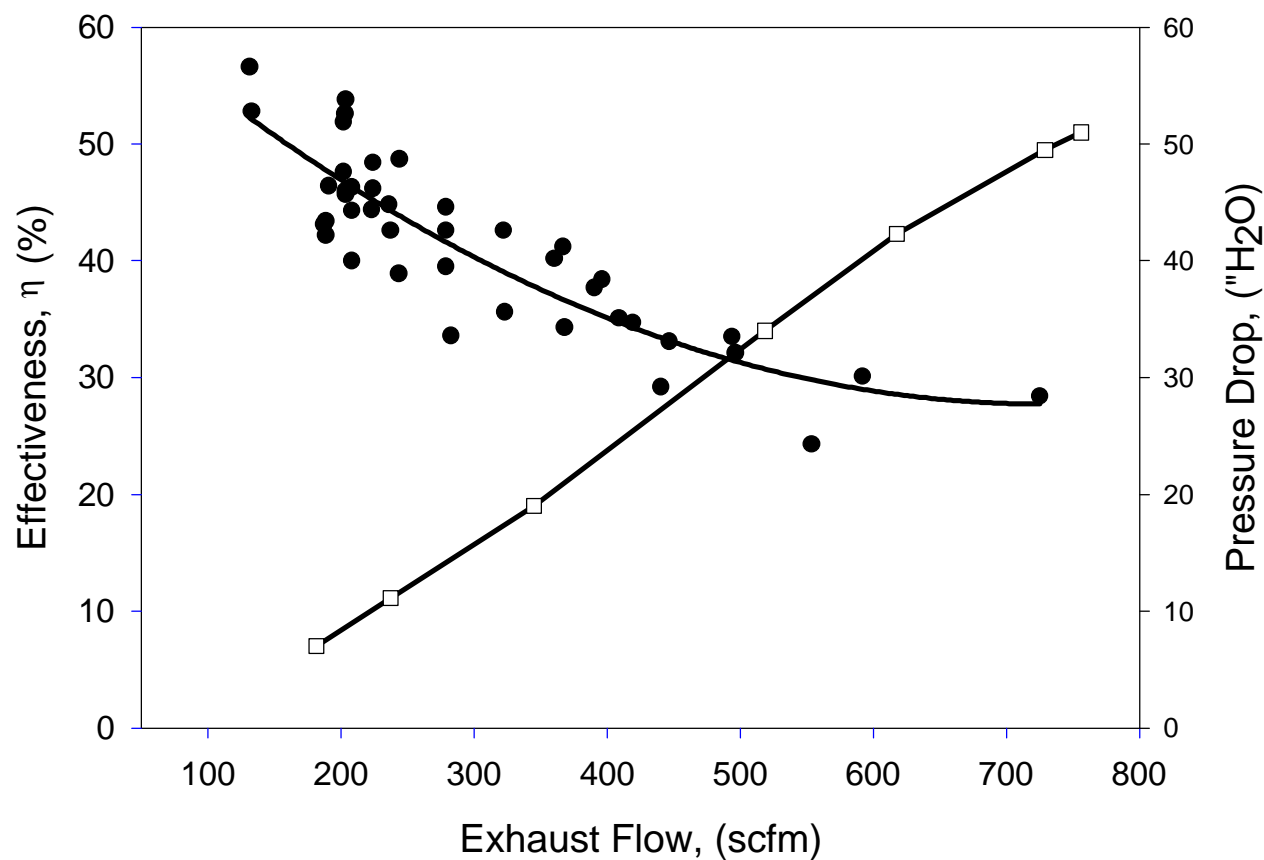


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Heat Recovery & Pressure Drop

Recuperator and Catalyst



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Summary of Testing

- © 'Proof of concept' demonstrated
- © 30-60% heat recovery
- © Acceptable back-pressure
- © > 95% reduction of CO and HC
- © > 80% PM reduction
- © Up to 45% NO_x reduction
depending on amount of fuel
injected

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Summary: The QuadCAT 4-way Catalytic Converter

Elements

© **Recuperator**

© **Fuel Injection and Control System**

© **Lean NOx Catalyst**

© **DPF/DOC**

Features

- Elevate catalyst temperature by recycling heat
- Noise abatement (replaces muffler/silencer)
- Simultaneous oxidation & reduction with controlled HC injection
- Rich cycling and high temperature cycling to reverse sulfur poisoning
- Regenerate DPF on demand, OR
- Optimize for NOx reduction
- Reduce NOx with HC as a reductant
- Non-precious metal based
- Filter and oxidize PM
- Oxidize CO and HC
- DOC is non-precious metal based



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Light-Duty QuadCAT Converter

© A QuadCAT Converter field unit installed on a Ceryx test vehicle



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